NORTHWESTERN UNIVERSITY

After-math: Optimizing Public-Private Approaches to Post-Disaster Debris Operations

The Haiti earthquake of January 2010 killed up to 300,000 people and damaged a wide region including Port-au-Prince, the capital. The quake left an estimated 25 million cubic meters of debris in the city's center; by the summer of that year less than 5 percent of the waste had been collected. In the fall of that year, the Haitian Reconstruction Commission asked a team led by Georgia Institute of Technology professor Özlem Ergun to help evaluate several large-scale debris-collection plans under consideration. Ergun was a natural choice because her research focused on optimizing logistics networks and she had co-founded and co-directed Georgia Tech's Health and Humanitarian Logistics Research Center, and advised the UN World Food Programme, the Centers for Disease Control, and multiple other humanitarian organizations, working closely with Pinar Keskinocak, one of the research center's co-directors.

Moreover, because of their previous work in debris-management, Ergun's team had won a National Science Foundation grant to conduct post-earthquake field research in Haiti earlier that year, including collecting extensive data and meeting with several agencies and contractors involved in the clean-up effort.[1] Based on their findings, Ergun and colleagues had written a *New York Times* opinion-editorial that recommended the UN, Haitian government, and other agencies form a debris-removal taskforce to address the problem more effectively. Thus the team was well-prepared to evaluate the proposed debris-collection plans.

Ergun spoke of the experience in a September 2013 talk hosted by Northwestern's Industrial Engineering and Management Science department, as part of its Humanitarian and Nonprofit Logistics Initiative.

A Complex and Costly Problem

Ergun's interest in post-disaster debris-management was first sparked in the aftermath of a series of tornadoes that had swept through the Atlanta area in early 2008. The city's emergency management team asked Ergun to help them prepare for future such disasters, given the complexity of the relief effort required. For example, in considering how to reopen blocked or damaged roads, city officials had struggled to decide the order in which to reopen them. The experience opened Ergun's eyes to the broad, complex set of challenges associated with post-disaster debris-management, whether related to natural disasters or terrorist attacks. Short-term issues, for example, include clearing debris to provide relief supplies (such as food and water) and ensure access to critical facilities like hospitals. Longer-term challenges include disposing properly of the debris to avoid ongoing threats to humans and the environment.

Poor post-disaster debris-management strategies and practices have very high costs, in part because of the scale of clean-up required. When Hurricane Katrina slammed into the U.S. Gulf coast in 2005, the amount of solid waste created would have taken 100 million years to form under non-disaster

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[1] The Georgia Tech students who helped with this research were Melih Celik, Alvaro Lorca, and Kael Stilp

circumstances. Not surprisingly, then, clean-up efforts represent an estimated 27 percent of total disaster costs. Debris-management is typically a public-private effort. In the United States, for example, the Army Corps of Engineers handles large-scale clean-ups for events designated as federal emergencies by the Federal Emergency Management Agency (FEMA). Local emergency management agencies typically handle debris-management operations for local events that do not receive that designation. In both cases, the public organizations involved may call on the help of multiple types of private contractors for clean-up.

As Ergun and her team gained more experience with debris-management efforts, including a long-term collaboration with FEMA and the Army Corps of Engineers, they understood the core challenge: While there are many guidelines for *what* to do at each stage of post-disaster clean-up efforts, there are few frameworks, models, or best practices for *how* to do it. Ergun has focused much of her research on addressing this issue.

A Disaster Operations Timeline

Part of the approach to post-disaster debris-management involves understanding the general timeline for disaster operations. The most logical time segments to consider are the pre-disaster, response, and post-disaster phases. The pre-disaster phase involves forecasts (such as for what kind and how much debris will be generated in a certain area by a disaster of a given magnitude), supply/equipment-procurement strategies, and debris-site management and planning. For example, FEMA uses the Hazus software-based methodology for estimating potential losses (physical, economic, social) associated with earthquakes, hurricanes, and other natural disasters of certain magnitudes. Ergun and her team also use this technology in their research. While pre-disaster is obviously an important phase, Ergun's research has targeted the response and post-disaster phases. One area of focus, for example, has been debris-clearance strategies, or how best to clear waste to reach affected areas. In the post-disaster phase, the research focuses on debris collection and disposal operations, processes requiring costly, large-scale efforts from humans and machinery.

Optimizing Haiti's Clean-up

Debris clearance was a major challenge in post-earthquake Port-au-Prince. When Ergun's team arrived for their initial research in mid-2010, only the city's major arteries had been cleared, with many roads still blocked and piles of debris everywhere. Ergun was eventually asked to assess debris collection plans for the city, as discussed below, and the team has been developing models that apply to debris-clearance challenges for half a dozen years. For example, determining the optimal sequence of blocked roads to clear requires taking into account relief-supply availability, medical-facility sites, and the numbers and locations of people in need, along with volumes of accumulated debris by location. Ergun's team has created a network-design model of the debris-clearance challenge that could be used to maximize the benefit (connecting people in need with supplies and treatment centers) and/or minimize the penalty (length of time that passes before such connections are made) within the system. The problem, however, is that in real-world post-disaster situations like Haiti's, only incomplete information is available for most of the variables involved; for example, there is no way of knowing exactly how much debris will be in each location beforehand. This element of unpredictability makes it difficult to apply "deterministic" mathematical models to the problem, or those that assume there are no random elements in the system. Even running such models of the debris-clearance problem on high-performance computers would yield suboptimal results. A "stochastic" mathematical approach—one that can be applied to systems with at least some random elements—is more promising, so Ergun's team used that concept in their debris-clearance model.

Central to the model is the idea that as more debris is cleared from the reachable parts of a region, more will be known about the volumes of waste in less reachable locations. In other words, as you gain more data about given parts of the system, you can better predict features of the entire system, delivering better forecasts overall. Ergun put a refined version of this "learn-as-you-go" model through rigorous tests. Overall, the model yielded a close-to-optimal solution in less than 40 percent of the computing time an optimal solution would have required, and performed very well on simulated debris-clearance scenarios (such as in post-earthquake Cambridge, Massachusetts).

In the fall of 2010 Ergun's team was asked to evaluate Haiti's plan for debris-collection, or how best to gather and dispose of cleared debris. The estimates at the time stated that collection would take about one year to complete. Here, Ergun's team developed a model that could divide the affected area into sub-regions assigned to work-teams with different capabilities and equipment. For this model, it was important to keep regions assigned to a given team contiguous and to take into account debris-to-travel-distance ratios. Using map data from a UN mission in Haiti, along with reports related to damage-assessment and other areas, Ergun's team categorized work-teams as "light," "medium," and "heavy" based on their capabilities/machinery and matched them with the needs of specific regions, then used the model to assess several aspects of the different debris-clearance plans.

Theory Meets Reality

Ergun's team's findings were startling: At the current rate of debris clearance the work would have taken up to *30 years* to complete, compared to the stated estimate of one year! For example, the current efforts relied overwhelmingly on manual labor (many teams did not even have hammers), including for clearing large volumes of debris at Port-au-Prince's center, where heavy machinery would have been much more effective. Ergun and her team shared their findings with the Reconstruction Commission and other relief-oriented organizations focused on Haiti. Though the parties involved saw the conclusions as valid overall, elections were imminent and the consensus was that it was best to have the to-be-elected government take responsibility for such a large-scale project. Hence the Haitian government in place at the time did not commit to a specific clean-up plan among those proposed. Unfortunately, even after the lengthy election process, little progress was made toward optimizing a debris-clearance plan. The inertia continues as of this writing.

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The challenges Ergun's team faced in Haiti highlight multiple tricky issues at the public-private intersection. First, debris-related issues may not always be seen as high priorities because they appeal to public emotion less immediately than, say, improving educational opportunities for underserved populations. But as discussed here, post-disaster debris-management is a complex, costly challenge with potentially large long-term impact on people, economics, and the environment. That necessitates greater awareness of the importance of debris-management, and a strategic approach to it, ideally based on effective frameworks and models. The second major challenge, then, is developing such frameworks and models—a domain in which research like Ergun's is exemplary.

Even when effective models are available, the greater complexities often involve political and organizational processes: motivating all public and private stakeholders to agree to and implement the best approach. Here, political pressures, economic factors, and private interests inevitably represent barriers to progress. While there may be answers to the *what* and *how* parts of the problem, the *why* remains elusive in many cases. As Ergun discovered in Haiti, politically charged processes and economic motivations are much harder to model and address than even the largest-scale debris-management challenges. Still, she believes that effective advocacy (such as the *New York Times* opinion-editorial mentioned earlier) and a highly collaborative approach can lead to more effective understanding and actions. "It's about building strong relationships among all parties—like FEMA and the Army Corps of Engineers—over time," she says. "My goal is to try to understand the problems they face and to develop user-friendly tools and models to help them, rather than black boxes that just spit out an 'answer.'" Strategic, application-oriented research like Ergun's highlights the potential for even more effective public-private approaches to debris-management and other high-stakes challenges.

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